

Resuscitation great

Resuscitation of avalanche victims: Evidence-based guidelines of the international commission for mountain emergency medicine (ICAR MEDCOM) Intended for physicians and other advanced life support personnel[☆]

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ABSTRACT

Background: In North America and Europe ~150 persons are killed by avalanches every year.

Methods: The International Commission for Mountain Emergency Medicine (ICAR MEDCOM) systematically developed evidence-based guidelines and an algorithm for the management of avalanche victims using a worksheet of 27 Population Intervention Comparator Outcome questions. Classification of recommendations and level of evidence are ranked using the American Heart Association system.

Results and conclusions: If lethal injuries are excluded and the body is not frozen, the rescue strategy is governed by the duration of snow burial and, if not available, by the victim's core-temperature. If burial time ≤ 35 min (or core-temperature ≥ 32 °C) rapid extrication and standard ALS is important. If burial time > 35 min and core-temperature < 32 °C, treatment of hypothermia including gentle extrication, full body insulation, ECG and core-temperature monitoring is recommended, and advanced airway management if appropriate. Unresponsive patients presenting with vital signs should be transported to a hospital capable of active external and minimally invasive rewarming such as forced air rewarming. Patients with cardiac instability or in cardiac arrest (with a patent airway) should be transported to a hospital for extracorporeal membrane oxygenation or cardiopulmonary bypass rewarming. Patients in cardiac arrest should receive uninterrupted CPR; with asystole, CPR may be terminated (or withheld) if a patient is lethally injured or completely frozen, the airway is blocked and duration of burial > 35 min, serum potassium > 12 mmol L⁻¹, risk to the rescuers is unacceptably high or a valid do-not-resuscitate order exists. Management should include spinal precautions and other trauma care as indicated.

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1. Introduction

In North America and Europe ~150 persons are killed by avalanches every year,¹ with most triggered by skiers, snowboarders and, in the USA and Canada, by snowmobilers.² Avalanches inflict even higher death tolls in developing countries; for instance avalanches claimed 284 lives in South East Anatolia in 1992, > 200 in Kashmir in 1995 and 135 in Kashmir in 2012. The total number of persons in avalanche terrain is unobtainable and mortality in these activity groups can only be roughly estimated. The first recommendations for on-site management and transport of avalanche victims,

based on survival analyses,^{3,4} case reports⁵ and case series,^{6–9} were proposed in 1996¹⁰ and 2001.⁴ The International Commission for Mountain Emergency Medicine (ICAR MEDCOM) established official consensus guidelines including an algorithm in 2002.¹¹ A systematic review of four prognostic factors¹² and an International Liaison Committee on Resuscitation (ILCOR) worksheet process were the basis of the recommendations for avalanche resuscitation in the 2010 Resuscitation Guidelines.^{13,14} Recommendations for transport and treatment decisions of hypothermic patients including avalanche victims have been recently developed.¹⁵ The ICAR MEDCOM sought to systematically develop evidence-based guidelines using a structured worksheet with the mandate to obtain final consensus among the ICAR MEDCOM.

2. Methods

The objectives, inclusion/exclusion criteria, working group and worksheet of 27 Population Intervention Comparator Outcome (PICO) questions (supplementary data) derived from earlier avalanche resuscitation recommendations⁴ were developed by the ICAR MEDCOM at a TOPIC meeting. The electronic database of Medline was searched via PubMed with the search terms (avalanche [All Fields]) and (hypothermia [All Fields]) and the database of EMBASE via OVID with (avalanche {Including Related Terms}) and (hypothermia {Including Related Terms}). The Cochrane Database of Systematic Reviews was searched with the terms (avalanche) and (accidental hypothermia). Additional hand searching of articles, reference texts and reference lists was also performed. All articles relevant to clinical management of victims of snow avalanches and related accidental hypothermia were extracted for further review. These were evaluated for quality and relevance to the PICO questions and recommendations were developed at a SCIENCE meeting. The recommendations were further examined and consensus was reached at a MANUSCRIPT meeting in Åre, Sweden, in October 2011. Classification of recommendations and level of evidence are ranked using the American Heart Association (AHA) system (Table 1).

3. Findings and recommendations

From a total of 3530 retrieved citations, 96 articles were classified as relevant and were subjected to full review.

Survival probability

The overall survival rate of avalanche victims is 77% (1453/1886).⁴ Survival depends on the grade and duration of burial and the pathological processes of asphyxia, trauma and hypothermia.

Grade of burial

Analysis of a Swiss sample showed that 39% (735/1886) of victims involved in an avalanche were completely buried, with survival in complete burials (i.e. burial of the head and chest¹) of 47.6% (350/735) versus 95.8% (1103/1151) in partial burials.⁴ Grade of burial is the strongest single factor for survival.

¹ In Europe the term *completely buried* refers to burial of at least the head and chest. In North America the term *completely buried* is reserved for when the individual is totally buried beneath the snow surface and *partially buried-critical* for when the individual is partially buried with at least the head under the snow surface and with breathing impaired.^{57,58} The term *critical burial* will be used hereafter to identify burials that impair breathing and therefore risk asphyxia.

Duration of burial

Biostatistical survival analysis of critically buried victims¹ in Switzerland and Canada shows a progressive non-linear reduction in survival as duration of burial increases and distinct phases.^{3,4,16} In Switzerland, survival probability remains above 80% until 18 min after burial (“survival phase”) and plummets thereafter to 32% (“asphyxia phase”), whereas the Canadian survival curve shows an earlier and steeper decline from 77% at 10 min to 7% at 35 min, which reflects a greater mortality from trauma and an earlier onset of asphyxia due to denser snow in some regions of Canada^{16,17} (Fig. 1). Supportively, hypoxia has been shown to be correlated to snow density in an experimental study.¹⁸ Another identifiable decrease in survival occurs at 90 min due to hypothermia combined with hypoxia and hypercapnia.⁴ The duration of burial is therefore an indication of pathology and should dictate treatment strategy.

3.1. Asphyxia

Asphyxia was found to be the most common cause of death in three case series that relied on autopsy, full forensic external examination and/or pre-mortem clinical findings.^{16,19,20} Asphyxia may occur in combination with trauma and hypothermia.¹⁶

3.1.1. Expediency

Survival decreases rapidly in the “asphyxia phase”, i.e. in the first 35 min.^{3,4,17}

Recommendations. Companions should locate and extricate buried victims expeditiously (Class 1, LOE B).

Organized rescue should be mobilized early (Class I, LOE B).

3.1.2. Duration of burial and airway patency

A systematic review¹² confirmed that a patent airway was essential for survival for >35 min of critical burial, with four of the analyzed retrospective studies describing survival to hospital discharge in victims buried >60 min who were found with patent airways. No survivors were reported in any of the 14 case-control and case series for victims with an obstructed airway and >35 min of burial. A prospective, randomized, crossover experimental study found that when breathing into a simulated air pocket subjects achieved a steady state of survivable hypoxia for at least 20 min in 39% (11/28) of uninterrupted tests.¹⁸ Other prospective experimental studies have indicated that redirecting gas exchange away from an air pocket, such as might occur in avalanche debris with large blocks or an opening to environmental air, improves oxygenation.^{21–23}

Recommendation. If burial >35 min, airway patency should be determined upon exposure of the face (Class I, LOE A).

The ancillary presence of an air pocket should be determined by digging from the side of the victim in order to not harm the victim or destroy the air pocket (Class I, LOE C).

3.1.3. Resuscitation

Resuscitation guidelines recommend standard CPR in hypoxaemic cardiopulmonary arrest.^{13,14} Ventilation should be combined with chest compressions, as compression-only CPR is inappropriate for avalanche burial.

Recommendations. Factors and decisions are integrated in a management algorithm (Fig. 2) (Class IIa, LOE C).

For victims buried <35 min found in cardiac arrest, presume asphyxia and initiate standard CPR with ventilations as soon as the head and chest are free regardless of airway patency (Class I, LOE B).

For victims buried >35 min found in non-asystolic cardiac arrest with a patent airway but who are not hypothermic ($\geq 32^\circ\text{C}$), presume asphyxia and initiate standard CPR with ventilations as soon as the head and chest are free (Class IIa, LOE B).

Table 1
Classification of recommendations and level of evidence according to the ACCF/AHA task force on practice guidelines.^a

Size of treatment effect		Size of treatment effect		Size of treatment effect	
LEVEL (Quality) of evidence (LOE)	CLASS I <i>Benefit » Risk</i> Procedure/Treatment should be performed/administered	CLASS IIa <i>Benefit » Risk</i> It is reasonable to perform procedure/administer treatment	CLASS IIb <i>Benefit ≥ Risk</i> Procedure/Treatment may be considered	CLASS III <i>No Benefit or Harm</i> Procedure/Treatment of no benefit or harmful	CLASS III <i>No Benefit or Harm</i> Procedure/Treatment of no benefit or harmful
LEVEL A	Recommendation that procedure or treatment is useful/effective.	Recommendation in favor of treatment or procedure being useful/effective.	Recommendation's usefulness/efficacy less well established.	Recommendation that procedure or treatment is not useful/effective and may be harmful.	Recommendation that procedure or treatment is not useful/effective and may be harmful.
Data derived from multiple randomized clinical trials or meta-analyses	Sufficient evidence from multiple randomized trials or meta-analyses.	Some conflicting evidence from multiple randomized trials or meta-analyses.	Greater conflicting evidence from multiple randomized trials or meta-analyses.	Sufficient evidence from multiple randomized trials or meta-analyses.	Sufficient evidence from multiple randomized trials or meta-analyses.
LEVEL B	Recommendation that procedure or treatment is useful/effective.	Recommendation in favor of treatment or procedure being useful/effective.	Recommendation's usefulness/efficacy less well established.	Recommendation that procedure or treatment is not useful/effective and may be harmful.	Recommendation that procedure or treatment is not useful/effective and may be harmful.
Data derived from a single randomized trial or nonrandomized studies	Evidence from single randomized trial or nonrandomized studies.	Some conflicting evidence from single randomized trial or nonrandomized studies.	Greater conflicting evidence from single randomized trial or nonrandomized studies.	Evidence from single randomized trial or nonrandomized studies.	Evidence from single randomized trial or nonrandomized studies.
LEVEL C	Recommendation that procedure or treatment is useful/effective.	Recommendation in favor of treatment or procedure being useful/effective.	Recommendation's usefulness/efficacy less well established.	Recommendation that procedure or treatment is not useful/effective and may be harmful.	Recommendation that procedure or treatment is not useful/effective and may be harmful.
Only consensus opinion of experts, case studies, or standard of care	Only expert opinion, case, or standard of care.	Only diverging expert opinion, case studies, or standard of care.	Only diverging expert opinion, case studies, or standard of care.	Only diverging expert opinion, case studies, or standard of care.	Only diverging expert opinion, case studies, or standard of care.

^a Manual for ACC/AHA Guideline Writing Committees (Accessed 01 September 2012, at <http://circ.ahajournals.org/site/manual/index.xhtml>).

For victims buried >35 min found in asystolic cardiac arrest with an obstructed airway, resuscitation may be initiated but can be terminated if not successful (Class I, LOE A).

3.1.4. Advanced airway

Advanced airway management (e.g. endotracheal intubation and supraglottic airway devices) performed by experienced personnel enables effective ventilation, reduces the likelihood of aspiration for avalanche victims in periarrest¹⁴ and may improve survival.²⁴ In prehospital settings with long transport times, endotracheal intubation is associated with improved survival.²⁵

However, complications are unacceptably frequent when performed by inexperienced providers.^{25,26} Supraglottic devices may be more efficient and safer than endotracheal intubation or bag-mask ventilation for less experienced rescuers.

Recommendations. For unresponsive victims advanced airway management should be performed if the rescuer is competent in this skill and if airway management succeeds within a reasonable time (Class I, LOE A).

For rescuers not experienced in advanced airway management, ventilation is most effective with mouth-to-mask or bag-mask techniques (Class I, LOE A).

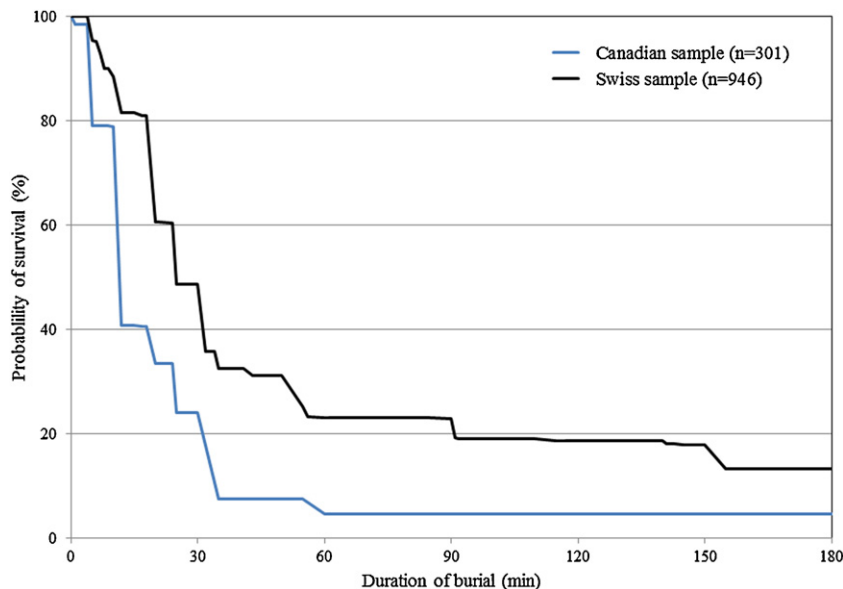


Fig. 1. Comparison of survival curves in Canada (black; n = 301) and Switzerland (grey; n = 946) from 1980 to 2005. Extracted from Haegeli et al.¹⁶ with permission from CMAJ.

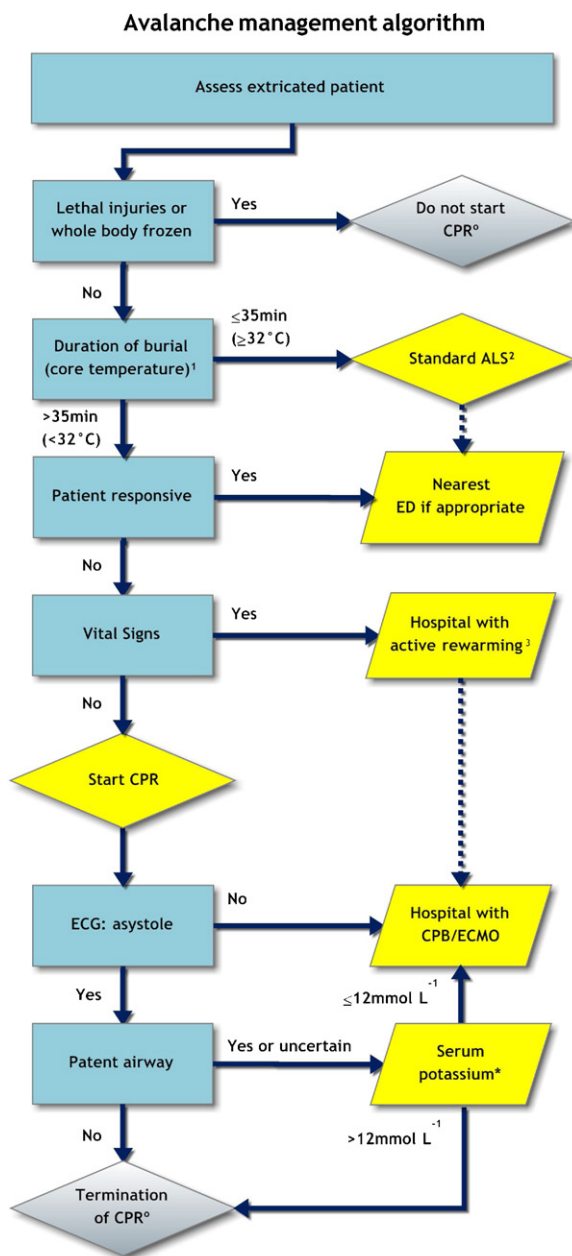


Fig. 2. Management of the buried avalanche victim. In all cases gentle extrication and spinal precautions. Where appropriate core temperature and ECG monitoring, oxygen, insulation, heat packs on trunk; 0.9% NaCl and/or 5% glucose only if an intravenous or intraosseous line can be established within a few minutes; specific trauma care as indicated. ⁰Clinicians may consider withholding resuscitation at the scene if it increases risk to the rescue team or if the victim is lethally injured or completely frozen. ¹If duration of burial is unknown core temperature may substitute. ²Initiate standard ALS including ventilations and chest compressions as indicated. Resuscitation may be terminated in normothermic patients if ALS is not successful after 20 min. Transport victims with concern of respiratory (e.g. pulmonary oedema) or other-system injury to the most appropriate medical centre. ³Hospital capable of advanced external or core rewarming. Patients who present with cardiac instability (ventricular arrhythmias, systolic blood pressure <90 mm Hg) or core-temperature <28 °C should be transported towards ECC rewarming. Defibrillation beyond three attempts may be delayed until core-temperature >30 °C. *If direct transport to ECC rewarming is practical, the nearest ED can be bypassed. If K⁺ at hospital admission exceeds 12 mmol L⁻¹, consider stopping resuscitation (after excluding crush injuries and consideration of the use of depolarizing paralytics); in an adult with K⁺ 8–12 mmol L⁻¹ and other factors consistent with non-survival, termination of resuscitation should be considered. ALS, Advanced Life Support; ED, Emergency Department; ICU, Intensive Care Unit; ECC, extracorporeal circulation.

For a potential survivor with a failed airway, hospital transfer should be hastened with early alert of appropriate support (Class I, LOE C).

3.1.5. Transport

Post-resuscitation care including therapeutic hypothermia is integral to improving survival.^{25,26} Mechanical chest compression devices improve rescuer safety and reduce manual energy expenditure and may improve outcome during transport.²⁶ Delayed onset of pulmonary oedema has been reported in avalanche victims with vital signs after short burials.²⁷

Recommendations. If resuscitation is successful or termination-of-CPR criteria are not met (see *Termination of CPR*) victims should be transported to the nearest hospital, preferably one with intensive care services (Class IIa, LOE C).

Mechanical chest compression devices and therapeutic hypothermia may be considered for prolonged transports (Class IIb, LOE B).

If victims present with signs or concern of respiratory or other system injury they should be transported to the nearest emergency department for advanced assessment and observation (Class I, LOE C).

3.2. Trauma

Trauma was the principal cause of death in 23.5% (48/204) of fatalities in western Canada,¹⁶ 5.5% (2/36) in Austria¹⁹ and 5.4% (3/56) in Utah.²⁰ However, in the Canadian sample major trauma, i.e. injury severity score (ISS) >15, was additionally found in 13.0% (12/92) of autopsied “asphyxia” fatalities. Chest trauma represented 45.8% (11/24) of single-system injuries; 52.1% (25/48) were found on the surface or not critically buried.¹⁶ In the Austrian sample 8.6% (9/105) of fatality cases had an ISS score >13 although only 5.5% (2/36) were ascribed to trauma; the two trauma fatalities were fracture-dislocations of the cervical spine.¹⁹ Similarly, in the Utah sample trauma was associated with asphyxia in 8.9% (5/56) of fatalities in addition to the 5.4% (3/56) ascribed to trauma alone; autopsies found head, abdominal and limb injuries to be common.²⁰ Differing rates are dependent on topographical factors (e.g. open versus forested terrain).¹⁶

3.2.1. On-site management

Current resuscitation guidelines emphasize spinal stabilization, chest decompression for tension pneumothorax, haemorrhage control, prompt evacuation to definitive care and consideration of permissive hypotension in the resuscitation of shock.^{13,14} Tourniquets are life-saving in exsanguinating limb injuries.²⁸ In traumatic cardiac arrest survival is approximately 5.6% and prolonged CPR >16 min is associated with a poor outcome.¹³ In severe head trauma outcomes are improved with early intubation and normoventilation while hypo- and hyperventilation result in poorer outcome.²⁹

Recommendations. Rescuers should provide adequate spinal stabilization throughout extrication, on-scene management and transport (Class I, LOE C).

Trauma measures include splinting, insulation and analgesia (Class I, LOE C).

Clinical teams should be skilled and equipped for thoracostomy, tourniquet application, intravenous or intraosseous cannulation with controlled fluid infusion in shock or for medication administration, advanced airway management, cricothyrotomy and antibiotics for open fractures (Class IIa, LOE B).

CPR should be initiated for traumatic cardiopulmonary arrest while searching for and managing treatable causes (Class I, LOE B).

Delay of transport for on-site management should be as short as possible; direct transport to a dedicated trauma centre is preferred (Class I, LOE C).

3.3. Hypothermia

Hypothermia is commonly diagnosed clinically in avalanche victims. A systematic review of five retrospective case series found that hypothermic cardiac arrest is survivable if associated with a patent airway.¹² Hypothermia is rarely listed as the principal cause of death as post-mortem signs are limited and asphyxia and trauma are frequently concomitant.¹⁶ At low core-temperatures the brain tolerates cardio-circulatory arrest >5 min without permanent damage.^{9,30,31}

3.3.1. Cooling rate

The cooling rate during burial is variable but may be accelerated by light clothing, sweating and exhaustion. Hypercapnia and hypoxia may increase cooling rate.^{23,32} This combination has been termed the “triple H syndrome,”¹⁸ although the interactions are not elucidated. A maximum cooling rate of 9°C h^{-1} was found during a burial of 100 min,³¹ while lesser cooling rates have been reported in other case series and reports^{33–35} and in experimental human³⁶ and animal studies.²³ At the maximum rate of 9°C h^{-1} a minimum time of 35 min is required for the core-temperature to drop $<32^{\circ}\text{C}$ and it is therefore concluded that the presence of a patent airway is essential for survival in any victim with a core-temperature $<32^{\circ}\text{C}$.^{12–14}

Recommendations. (See Table 2 for the management of victims at different stages of hypothermia and Fig. 2 for the management of avalanche victims.)

For victims in cardiac arrest with a core-temperature $<32^{\circ}\text{C}$ and a patent or unknown airway initiate resuscitation (Class I, LOE A).

For victims in asystolic cardiac arrest with a core-temperature $<32^{\circ}\text{C}$ and an obstructed airway, presume asphyxia and withhold resuscitation (Class I, LOE A).

3.3.2. Rescue collapse

Collapse of hypothermic avalanche victims during rescue is associated with lethal arrhythmias, according to case reports.^{31,35} Mechanical stimulation has been shown to produce lethal arrhythmias in a porcine model of hypothermia.³⁷ A core-temperature of 32°C is considered the threshold for ventricular fibrillation.³⁸

Recommendations. ECG monitoring² should be applied upon extrication and continued during transport, using maximum amplification if complexes are small (Class I, LOE B).

Mechanical irritation of hypothermic victims should be minimized, avoiding excessive limb extension, rough transport and unnecessary chest compressions (Class I, LOE B).

Transport victims in the horizontal position (Class I, LOE C).

3.3.3. Core-temperature

Accidental hypothermia has been defined as “an unintentional reduction in core-temperature $<35^{\circ}\text{C}$.”^{13,15,38} Hypothermia may be staged using the “Swiss staging” system (based on clinical findings as well as core temperatures),^{13,15,39} which corresponds with the system of Danzl.³⁸ Hypothermia is often combined with asphyxia and trauma, rendering clinical signs unreliable. Oesophageal temperatures are more reliable than other temperatures⁴⁰ and are recommended in intubated patients.^{13,38,41} Alternatively, epitympanic temperatures are reasonably accurate in the non-intubated patient not in cardiac arrest, given a non-obstructed ear canal and

correct application including insulation from cold air.^{10,42} In a cold environment only thermistor-based, not infrared-based, epitympanic thermometers correlate well with core-temperature.⁴² In human studies epitympanic, brain and bladder temperatures correlated well,⁴³ while rectal temperatures lagged behind oesophageal temperatures during rewarming.^{36,40}

Recommendations. Don't rely on clinical hypothermia staging alone when asphyxia and/or trauma occur (Class I, LOE C).

Obtain core-temperatures when hypothermia has management significance, with an oesophageal probe in the intubated or epitympanic thermistor probe in the non-intubated victim (Class I, LOE B).

Rectal temperature may be used to gauge hypothermia initially (Class IIa, LOE B).

3.3.4. Insulation

Afterdrop refers to continued decline in temperature after removal from cold. All guidelines recommend insulation from further cooling and most recommend removal of wet clothing,^{4,11,15,38} which may however increase heat loss in a cold, windy environment. Manikin studies found that increasing insulation over wet clothing produced a similar reduction in heat loss compared to removing clothing⁴⁴ and that a windproof outer wrap over the insulation assembly is necessary.⁴⁵

Recommendations. Hypothermic victims should be insulated against further heat loss with dry, low-conductivity, whole-body assemblies covered in a windproof and water-resistant outer shell³ (Class I, LOE B).

Remove wet clothing only if the victim can be insulated effectively; cut clothing cautiously if victim has a hypothermia staging of moderate or worse (Class I, LOE C).

3.3.5. Out-of-hospital rewarming

Applying heat packs may improve comfort although core-temperature may not be increased.⁴⁶ Warmed humidified oxygen provides limited benefit.^{13,14} Warmed infused fluids provide only minimal contribution to rewarming, with a hypothetical rise of $0.3^{\circ}\text{C L}^{-1}$ of 40°C fluid,⁴⁷ and are difficult to keep warm in the field.

Recommendations. Apply safe heat sources such as covered chemical heat packs to the trunk (Class IIb, LOE B).

Maintain infusate at $38–42^{\circ}\text{C}$ (Class IIb, LOE B).

3.3.6. Oxygen

Adequate oxygenation may help reduce the risk of post-rescue collapse as it is known to improve myocardial stability.³⁸ Pulse-oximetry is inaccurate with cold exposure due to peripheral vasoconstriction as well as device malfunction, high altitude and bright ambient light.⁴⁸

Recommendations. Apply supplemental oxygen to significantly hypothermic victims (Class IIb, LOE C).

Pulse-oximetry may be unreliable (Class IIb, LOE B).

3.3.7. Advanced airway

Advanced airway placement provides oxygenation and airway protection from aspiration and is low risk for triggering malignant arrhythmias.⁴⁹ Depolarizing neuromuscular paralytics (e.g. succinylcholine) may increase the serum potassium level and affect subsequent decisions.

Recommendation. Consider the impact of depolarizing paralytics on serum potassium if the latter is planned for resuscitation or advanced rewarming decisions (Class I, LOE B).

² ECG monitoring may be performed with a monitor-defibrillator or an AED. AED monitoring is best with a device that has a monitor window.

³ These may be purpose-built rescue bags with insulated hoods, or assemblies of blankets enclosed in aluminium foil combined with head protection.

Table 2
Staging and management of hypothermic avalanche victims.

CT	Swiss staging ^a	Danzl ^b	Treatment	Transfer
35–32 °C	Hypothermia I: conscious, shivering	Mild hypothermia	<ul style="list-style-type: none"> • Move actively • Drink warm, sweetened fluids^c • Insulation 	Nearest ED
32–28 °C	Hypothermia II: impaired consciousness, without shivering	Moderate hypothermia	<ul style="list-style-type: none"> • Gently extricate and immobilize horizontally • Continuously monitor with ECG and core temperature • Full body insulation • Apply chemical heat packs to trunk • Administer oxygen • Place iv or io line, without considerably delaying transport 	Stable circulation: hospital with active rewarming facilities Unstable circulation: hospital with ECMO/CPB
28–24 °C	Hypothermia III: unconscious	Severe hypothermia	Additionally - <ul style="list-style-type: none"> • Protect upper airway: Recovery position or if reasonable advanced airway management • Try to avoid depolarizing paralytic agents • Withhold or carefully dose drugs (slow metabolism!) 	Stable circulation: hospital with active rewarming facilities Unstable circulation: hospital with ECMO/CPB
<24 °C ^d	Hypothermia IV: no vital signs	Severe and profound (<20 °C) hypothermia	Additionally - <ul style="list-style-type: none"> • Standard CPR • Avoid excessive defibrillation attempts 	Hospital with ECMO/CPB

^a Durrer et al.³⁹ This Swiss staging system was adopted by the 2010 ERC Guidelines for Resuscitation. The clinical signs in the Swiss staging system reflect the effect of hypothermia only. Considering that consciousness can be impaired by asphyxia and trauma, core temperature measurement is necessary to assess the severity of hypothermia.¹³

^b Danzl.³⁸

^c If transport delayed >2 h and no signs of trauma that would necessitate anaesthesia.

^d 13.7 °C is the lowest core temperature recorded in a survivor of accidental hypothermia.

ALS, advanced life support; CT, core temperature; ECMO/CPB, extracorporeal rewarming/cardiopulmonary bypass; ED, emergency department.

3.3.8. CPR

In severely hypothermic patients respirations and pulse may be indistinct.

Recommendations. Check carefully for vital signs and ECG activity for up to 1 min (Class IIb, LOE C).

Initiate CPR if signs of life are absent at standard BLS rates (Class IIa, LOE B).

3.3.9. Defibrillation

Defibrillation of severely hypothermic patients (<28 °C) presenting with ventricular fibrillation is unsuccessful in most cases, though defibrillation thresholds vary individually and successful defibrillation with core-temperatures as low as 25.6 °C has been reported.⁵⁰ Due to the paucity of animal and human studies and conflicting results, experts disagree on the application of defibrillation with core-temperatures <30 °C.^{13,14} The 2010 ERC-guidelines¹³ recommend a maximum of three defibrillations at <30 °C while the 2010 AHA-guidelines¹⁴ recommend standard defibrillation while rewarming.

Recommendations. Use standard defibrillations when indicated, regardless of core-temperature; repetitions beyond three attempts may be delayed until core-temperature >30 °C and should be avoided if they cause interruption of CPR and/or transport to rewarming (see *Transport*) (Class IIa, LOE B).

3.3.10. ALS medications

Similar to defibrillation, experts disagree on the effectiveness of advanced life support (ALS) drug therapy with core-temperatures <30 °C.^{13,14} The 2010 ERC-guidelines¹³ recommend no ALS drugs, while the 2010 AHA-guidelines¹⁴ allow vasopressors in cardiac arrest. Vasopressors may induce arrhythmias and increase risk of frostbite. Drug metabolism is decreased with low core-temperature.⁵¹

Recommendation. It may be reasonable to consider vasopressors concurrently with rewarming strategies (Class IIb, LOE B).

3.3.11. Transport

For hypothermic victims with a perfusing rhythm, active external rewarming such as forced-air rewarming is successful.^{13,14,38} For severely hypothermic victims in cardiac arrest, extracorporeal rewarming resulted in return of spontaneous circulation (ROSC) in 23 of 186 and survival to hospital discharge in 8 of 186 avalanche victims examined in a systematic review of seven case series and reports.¹² Complications after extracorporeal rewarming commonly include pulmonary oedema,^{31,52} which may explain improved survival with extracorporeal membrane oxygenation (ECMO) compared to cardiopulmonary bypass (CPB).⁵²

Recommendations. For victims with core-temperature <32 °C but no cardiac instability, i.e. systolic blood pressure ≥90 mmHg and no ventricular arrhythmias, and core-temperature >28 °C, transport to the nearest appropriate hospital for active external and minimally invasive rewarming (i.e. warm environment; chemical, electrical, or forced air heating packs or blankets; warm iv-fluids) is recommended¹⁵ (Class I, LOE B).

Hypothermic victims with a patent or unknown airway, with cardiac instability or a core-temperature <28 °C, or in cardiac arrest, should be transported to a centre with ECMO or CPB; if ECMO/CPB is not available transport to an appropriate hospital for alternative active internal rewarming (e.g. thoracic lavage) with continued CPR is recommended (Class I, LOE B).

Notify the ECMO/CPB centre before departure (Class IIa, LOE C).

3.3.12. Serum potassium

Serum potassium was predictive of survival for hypothermic cardiac arrest victims in a systematic review of prognostic factors in avalanche resuscitation,¹² with higher levels and poorer survival in asphyxiated victims. The highest admission serum potassium with ROSC was 8 mmol L⁻¹,⁸ while the highest level with survival was 6.4 mmol L⁻¹.³³ In accidental hypothermia of any origin the highest admission potassium of a survivor was 11.8 mmol L⁻¹ in a 31-month-old child exposed to freezing weather.⁵³

Recommendations. For hypothermic victims in asystolic cardiac arrest where duration of burial or airway patency is unknown or where a decision for prolonged resuscitation or long transport to a centre for ECMO/CPB needs confirmation, a serum potassium $<8 \text{ mmol L}^{-1}$ would indicate continued action, $>12 \text{ mmol L}^{-1}$ would indicate termination of resuscitation and $8\text{--}12 \text{ mmol L}^{-1}$ in an adult victim should be considered with other factors (Class I, LOE A).

3.3.13. Prognosis

Asphyxia markedly reduces survival in hypothermic cardiac arrest despite extracorporeal rewarming.^{6–8,52} The lowest core-temperature reported to date for a survivor of accidental hypothermia is 13.7°C in a victim trapped in a waterfall gully³⁰ and 19°C in a victim of avalanche burial.⁵

Recommendation. Victims of hypothermic cardiac arrest found with a patent or unknown airway and who are otherwise deemed possible survivors should be resuscitated until rewarmed to a core-temperature $>32^\circ\text{C}$ before a final decision is made (Class I, LOE C).

3.4. General measures

3.4.1. Oral fluids

Two Cochrane Systematic Reviews and the practice guideline of the American Society of Anesthesiologists found no evidence of adverse effects from clear fluids up to 2 h prior to surgery in otherwise healthy patients with no abnormal risk of regurgitation or aspiration.⁵⁴

Recommendations. Alert victims not requiring sedation or anaesthesia within 2 h may drink warmed, clear, calorie-containing, non-alcoholic, non-caffeinated fluids to sustain hydration and spontaneous rewarming (Class IIb, LOE B).

3.4.2. Activity

Recommendation. Alert mildly hypothermic victims ($35\text{--}32^\circ\text{C}$) may exercise to rewarm (Class IIa, LOE C).

3.4.3. Organized rescue

Recommendations. Organized rescue teams should mobilize promptly, ideally by helicopter, and should include clinicians skilled in mountain emergency medicine and be staffed according to the number of buried victims (Class IIa, LOE C).

Dogs and handlers may accompany organized rescue teams to find completely buried victims. Once all victims have been located there is no use for dogs and handlers (Class IIa, LOE C).

All staff should have appropriate safety equipment, especially avalanche transceivers and airbags (Class I, LOE B).

Medical equipment should include core-temperature and ECG monitor/defibrillator devices and appropriate medications; all instruments should be insulated and have fully-charged batteries (Class I, LOE B).

The potential risk to the rescuers must be evaluated, taking *less risk after longer burials* (Class IIb, LOE C).

3.4.4. Triage

A multiple casualty incident may initially overwhelm rescuers, and limited resources should be allocated to those most likely to survive.⁵⁵

Recommendations. When resources are overwhelmed by multiple victims in cardiac arrest priority should be given to those with a cardiac rhythm, a higher core-temperature and other favourable factors (Class IIb, LOE B).

3.5. Termination of CPR

The very poor survival of patients suffering prehospital normothermic asystolic cardiac arrest has resulted in validated EMS termination-of-resuscitation rules that have been incorporated into a guideline for mountain rescue (Class IIb, LOE C).⁵⁶

Recommendations. Resuscitation may be terminated (or withheld) when rescuer safety is unacceptably high, lethal injuries such as decapitation or truncal transection have occurred, the body is completely frozen, a valid do-not-resuscitate order exists, or limitations in transport or other logistics render resuscitation futile (Class I, LOE C).

Resuscitation may be terminated in unwitnessed cardiac arrest when, after 20 min of resuscitation, there has been no ROSC with no shock advised by AED or only asystole seen on ECG with no hypothermia or other special circumstance warranting extended CPR (Class IIa, LOE A).

4. Conclusions

The algorithm for the management of avalanche victims is shown in Fig. 2. If lethal injuries are excluded and the body is not frozen, the rescue strategy is governed by the duration of snow burial and, if not available, by the victim's core-temperature. If burial time ≤ 35 min (or core-temperature $\geq 32^\circ\text{C}$) rapid extrication and standard ALS is important. If burial time >35 min and core-temperature $<32^\circ\text{C}$, treatment of hypothermia including gentle extrication, full body insulation, ECG and core-temperature monitoring is recommended, as well as advanced airway management if appropriate. Unresponsive patients presenting with vital signs should be transported to a hospital capable of active external and minimally invasive rewarming such as forced air rewarming. Patients with cardiac instability or in cardiac arrest (with a patent airway) should be transported with uninterrupted CPR to an ECMO/CPB rewarming centre. Management should include spinal precautions and other trauma care as indicated.

Conflicts of interest statement

None of the authors have a commercial or industrial conflict of interest. H.B., J.B., B.D., P.P. and K.Z. have published on hypothermia. H.B. receives support as the head of the Institute of Mountain Emergency Medicine, EURAC research.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.resuscitation.2012.10.020>.

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